Non-natural Deaths of Children in Europe Between 1990–2021 – A Systematic Review

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Tiivistelmä – Referat – Abstract

Tämä systemattinen kirjallisuuskatsaus tarkastelee 1–15 -vuotiaiden lasten ei-luonnollisia kuolemia Euroopassa, ja sen tarkoituksena on luoda pohja tehokkaampien toimintasuunnitelmien kehitykselle näiden kuolemien estämiseksi. Kirjallisuushaku tehtiin OvidMEDLINE -tietokannassa ja katsaukseen sopivien artikkeleiden valinta tapahtui etukäteen määritettyjen sisällyttämiskriteerien perusteella. Tutkimusharhan riskiä valituissa tutkimuksissa arvioitiin Joanna Briggs -instituutissa kehitetyn kriittisen arvioinnin tarkistuslistalla (Critical Appraisal Checklist).

Kaikkiaan 43 artikkelia valittiin sisällyttämiskriteerien perusteella katsaukseen. Lähes kaikissa tutkimuksissa tutkimusotoksena oli koko väestö, ja kuolleisuusdata oli kerätty virallisista rekistereistä. Artikkeleita, joissa viimeisin tutkimusvuosi ulottui 2010-luvulle (n=12), oli merkittävästi vähemmän, kuin niitä, jossa se ulottui 2000-luvulle. Lasten itsemurhat olivat kaikista tutkituin aihe.

Yleisesti, 90-luvun jälkeen ei-luonnollisten kuolemien ilmaantuvuus on laskenut. Laskun takana on merkittävässä osassa kuljetustapaturmakuolemien ja muiden tapaturmakuolemien väheneminen. Myös itsemurhien ilmaantuvuus laski. Henkirikosten esiintyvyys pysyi samana tai hieman nousi. Pojat olivat useissa kuolemanluokissa yliedustettuina. Sukupuolten välinen kuilu kuitenkin kaventui

tutkittuna ajanjaksona, erityisesti itsemurhien kohdalla. Tuloepätasarvo ei-luonnollisen kuolleisuuden suhteen eri Euroopan maiden välillä on edelleen ajankohtainen ongelma.

Lasten ei-luonnollisten kuolemien epidemiologiaa tulee tutkia vielä lisää, sillä kehitysaskelia näiden kuolemien estämisen ja lasten terveyden edistämisen suhteen voidaan vielä ottaa. Tämä katsaus luo pohjan jatkotutkimuksille, jotka käsittelevät lasten ei-luonnollisten kuolemien epidemiologiaa.

(182 sanaa)

Deaths due to external causes (non-natural deaths) constitute a significant part of child mortality globally and also in Europe. Epidemiological literature on non-natural deaths among children in Europe was reviewed in an aim to provide a basis for the development of more effective preventive strategies. Epidemiological studies were searched from the OvidMEDLINE database, and articles were selected based on predefined inclusion criteria. The risk of bias was assessed with a critical appraisal checklist of Joanna Briggs Institute.

In all, 43 articles met inclusion criteria. Most studies covered entire populations and mortality data was collected from official registries. Suicide was the most popular external cause of death studied. Significantly less study time periods extended to the 2010s (n=12) compared to the 2000s (n=25). In general, the incidence of non-natural deaths has decreased from 1990 to 2021, which in the most part is due to the reductions in transport-related and other non-intentional non-natural deaths. Reductions were observed in suicides as well. More research is needed as further advances in reducing non-natural mortality can be achieved. The present review

builds a foundation for future research studies addressing epidemiology of non-natural deaths in children.

(192 words)

Avainsanat – Nyckelord – Keywords

Forensic medicine; Child Mortality; Europe; Prevention

Säilytyspaikka – Förvaringställe – Where deposited

Muita tietoja – Övriga uppgifter – Additional information

1 INTRODUCTION

Deaths due to external causes (non-natural deaths) constitute a significant part of child mortality globally. For children, the burden of accidental injury deaths is nearly half of all deaths, increasing with age and lower economic status of the country (1). There is a major margin for prevention in this category of child deaths, as is suggested by varying injury mortality rates between countries (2–4). In the geographical region of Europe, nearly 75% of all accidental injury deaths in the age group 5-19 could be prevented, if countries with highest rates matched the ones with the lowest (5). Similarly, Petridou et al. estimated this number to be between 30% and 50% in most European countries for children aged 0-14 (4).

To the best of my knowledge, there are no systematic reviews addressing all non-natural deaths comprehensively among children in Europe after 1990. On the other hand, sudden infant death syndrome (SIDS) and other causes of infant death defined as non-natural have received wider attention. In a systematic review on unintentional injury deaths, Imamura et al (2012) described threats to breathing to be the leading cause of non-natural infant death, while in the case of older children aged 5 and above, transportation accidents play a greater role in unintentional deaths in several countries (3) Similar results were obtained in a systematic review by Adeloye et al (2018), providing a crude global annual injury mortality rate of 32·7 per 100 000 for children aged 1–4, traffic accidents and drowning representing one in three and one in four injury deaths, respectively (2). However, as the developmental stage, daily activities and interaction with the world differ greatly between an infant and an older child, both age groups should be addressed independently, also when it comes to external cause mortality.

The aim of this systematic literature review was to provide a comprehensive overview of non-natural deaths of children aged 1–15 in Europe from 1990 to current day, and to describe differences and temporal trends in mortality between countries and age groups. As such, the fundamental aim of the review was to

provide an extensive basis to guide subsequent research and development of tools for preventive strategies to reduce non-natural mortality among children in general, and particularly in Europe.

2 MATERIALS AND METHODS

The literature search was performed in the Ovid MEDLINE database in March 2021. In accordance with the aims of the review, manuscripts were identified for inclusion by the following criteria:

1. The main focus of the article was on non-natural deaths/deaths by external cause. Both International Classification of Diseases, versions 9 and 10 (ICD-9 and ICD-10, respectively) were used to report causes of death during the timeframe of this study (Supplementary Table 1) (6,7). Studies with verbal descriptions of causes of death, where a definite conversion to ICD-coding was achievable, were also included.
2. At least one of the age groups studied was between the ages of 1 and 15.
3. The article focused on the time period of 1990 to 2021.
4. The article addressed one or more countries, subregions or institutes of the geographical region of Europe.

Studies that included persons of age under 1 or over 15 (e.g. 0–4 or 1–19) or time period(s) extended previous to 1990 (e.g. 1987–1991) were excluded. In addition, studies concerning non-fatal injuries and non-general population samples with predisposing factors (e.g. certain diseases, medications) were excluded.

In MEDLINE, three command groups were utilised to find articles. All terms within each command group were combined with Boolean operator OR. First command group included Medical Subject Heading (MeSH) terms and terms with .mp. - command based on ICD-10 categories on external causes of death. Explode-

command was applied on all MeSH-terms with exception of Suicide/, which would have thereby included attempted suicides as a subcategory. A modified OvidMedline filter children-focussed was used as a second command group (8). Transcript for the filter was sought and commands regarding newborns, neonates, infants, toddlers and babies were excluded from the filter. An exploded MeSH-term Europe was used as a third command group. All groups were combined with Boolean operator AND. The search was limited to articles in english language, discussing humans, containing an abstract and a publication date from 1990 to the current day. The search syntax is presented in Supplementary Table 2.

Articles eligible for the final review were selected by one author (JK), based on inclusion criteria defined previously. In case of uncertainty, thesis supervisors (AS and PO) were consulted. First, titles of interest were selected for examination of the abstracts. Articles fitting the inclusion criteria were read in full. The references of each selected full text article were also reviewed for eligible papers. Mortality data was then manually collected from each article selected for the present review.

Outcomes were defined as deaths due to an external cause and reported as annual mortality rates (AMR, n per 100 000 per year). Outcomes were grouped on the basis of ICD-10 codes presented in Supplementary Table 1.

If a paper discusses a subcategory of the predefined categories or if ICD codes are not addressed in the study, it will be mentioned separately. All time points not fitting our time period studied and age groups too broad were excluded.

Other variables collected were population size, age groups, years studied, and number of outcomes. If the population size wasn’t mentioned in the paper, it was estimated using online censuses (9). To provide comparable results, AMRs were calculated in case they weren’t presented in an article.

To assess the risk of bias in selected articles, the critical appraisal checklist of Joanna Briggs Institute was used. The nine-piece questionnaire is developed for

systematic reviews assessing questions of prevalence, and in the context of the present review, mortality. (10)

3 RESULTS

3.1 Literature search

The OvidMEDLINE search initially resulted in a total of 744 hits, excluding one duplicate reference. First, based on the title, papers were excluded as the focus was not on mortality; they focused on natural deaths; they studied non-natural deaths in infants or adults only; the sample populations had predisposing factors for non-natural deaths; or the time frame studied was before 1990. The abstracts were then assessed, and the articles meeting the initial inclusion criteria were read in full. Reasons for exclusion after initial inclusion varied from age groups or time periods being too broad; focus not being on mortality; having samples with exposure to factors affecting mortality; to an article being a systematic review; or having the same data as one article already selected. Finally, additional articles were identified inspecting the references of the selected papers. There were in total 43 eligible articles which are presented in *Table 3*. The entire selection process is described as a flowchart in *Figure 1*.

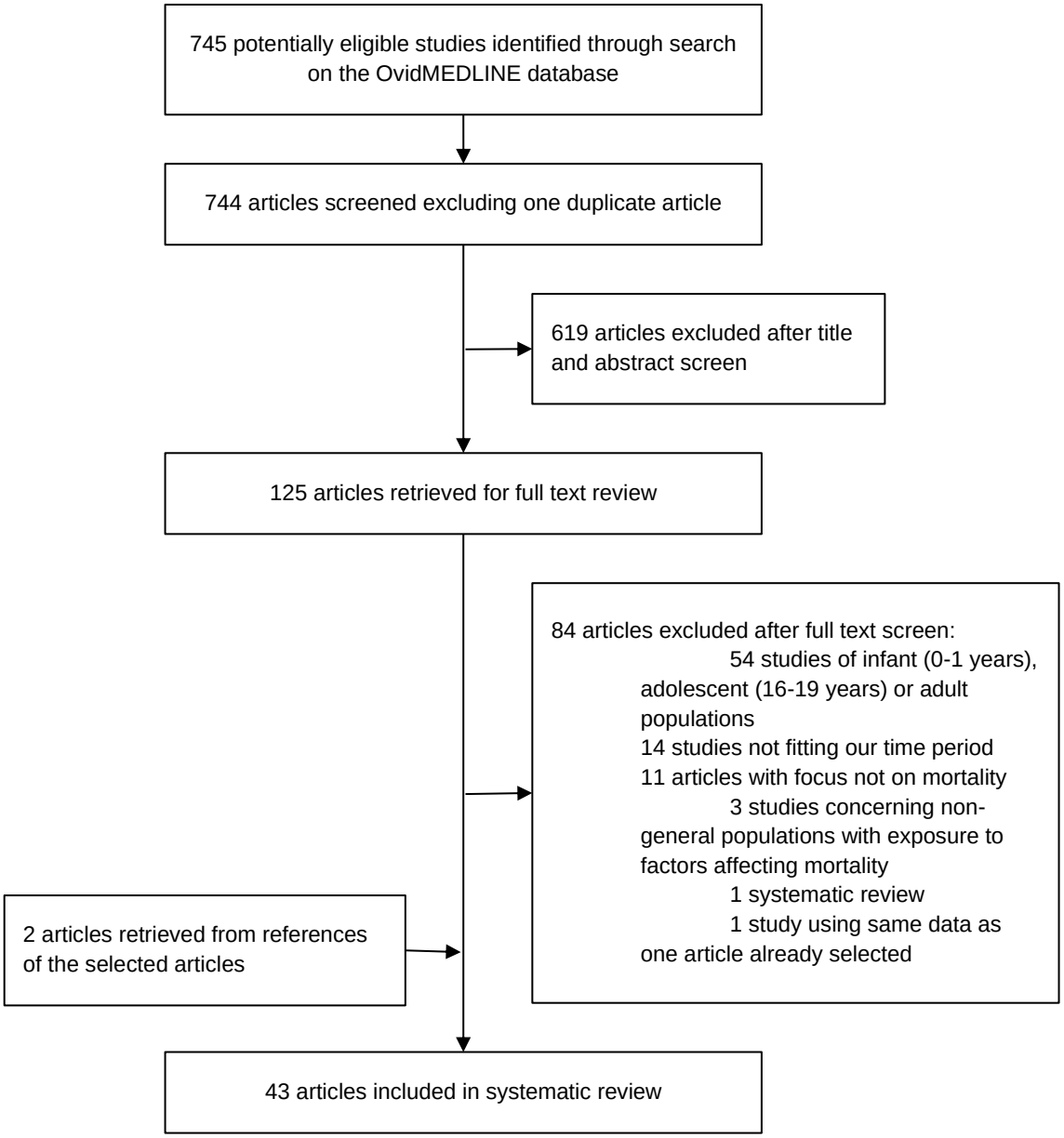

Figure 1. The flowchart presents the article selection process. A total of 43 articles were included for the present review.

3.2 Study characteristics

Table 1 describes the characteristics of studies included in the present review. Majority of the papers addressed the 2000s, and roughly one in four extended to the 2010s. Source population size varied from 10 000 children in regional studies to international studies with populations exceeding 10 000 000 children. Most studies were based on a source population of less than a million children. More

than half of the studies addressed multiple age groups and more than half provided mortality estimates separately for males and females. ICD-10 coding was available in one in four selected papers. Most studies were on one outcome, while roughly one in five had two or more outcomes.

Table 1. Characteristics of studies included in the present review.

Study characteristics	n	%
Total	43	100·0%
Latest year studied		
1990–1999	6	14·0%
2000–2009	25	58·1%
2010-2021	12	27·9%
Sample size		
10 000–100 000	3	7·0%
100 000–1 000 000	21	48·8%
1 000 000–10 000 000	10	23·3%
>10 000 000	9	20·9%
Sexes studied separately		
Yes	18	41·9%
No	25	58·1%
Multiple age groups		
Yes	18	41·9%
No	25	58·1%
ICD coding used 1)		
ICD-9	6	14·0%
ICD-10	12	27·9%
Multiple	11	25·6%
Not reported/verbal definitions	14	32·6%
Number of outcomes with #n or incidence		
1	34	79·1%
2–5	4	9·3%
>5	5	11·6%

1) International Classification of Diseases

As seen in *Table 2*, more than a half of the studies were either focused on suicides or regarded them as one of the main topics. Non-intentional deaths other than transport-related were studied in 10 papers, and five of these focused on one single cause of death.

Table 2. External causes of death classified according to main topics in the articles.

Main topics, non-natural deaths	n	%
Total	43	100·0%
All causes	11	25·6%
Transport-related	9	20·9%
Other non-intentional	10	23·3%
Suicide and/or undetermined	24	55·8%
Assault and/or undetermined	10	23·3%

Table 3. Summary of the articles included in the present review (in alphabetical order by the first author).

Reference	**Country, Region**	**Source population size**	**Age groups**	**Years studied**	**Outcomes 1)**
Armour-Marshall et al 2012[20]	Europe	large	1–14	1993–2008	Transport-related, Falls, Drowning, Poisoning, Fire/Smoke, Other non-intentional external, Suicide, Assault
Bacopoulou et al 2015[22]	Greece	~550 000	10–14	2000–2009	All external, Road traffic crashes*, Suicide
Baralic et al 2010[42]	Belgrade (Serbia)	~240 000	1–14	1991–2005	Assault
Berkelmans et al 2020[29]	Netherlands	~1 000 000	10–13, 14	2013–2017	Suicide X60-X84
Davies et al 2020[50]	UK	~11 500 000	1–14	2013–2015	Burns (T20-T32**)

Reference	Country, Region	Source population size	Age groups	Years studied	Outcomes 1)
Dervic et al[30]	Austria	~900 000	10–14	1990–2001	Suicide E950-959
Fajkic et al 2010[31]	Bosnia and Herzegovina	~250 000	10–14	2002–2006	Suicide E950-959
Fornes et al 1995[43]	Paris (France)	~1 000 000	(0-)1–4, 5–9, 10–14	1990–1993	Homicide
Grajda et al 2016[17]	Poland	~7 000 000	1–4, 5–9, 10–14	1999–2012	Transport-related V01-V99, Y85; Falls W00-W19, Drowning W65-W74, Suffocation/Strangulation W75-W84, Poisoning X40-X49, Other external, non-intentional W20–W64, W85–W99, X00–X39, X58–X59, Y35–Y36, Y40–Y89; Suicide X60-X84, Y87.0; Assault X85-Y09, Undetermined Y10-Y34, Y87.2, Y89.9
Groholt et al 1998[35]	Norway	~250 000	10–14	1990–1992	Suicide
Javouhey et al 2016[25]	Rhone (France)	~270 000	1–13, 1–4, 5–9, 10–13	1996–2001	Road accident*
Kivistö et al 2009[27]	Finland	~1 000 000	5–15	1994–2003	Poisoning X40-X49, X60-X69, X85- X90, Y10-Y19
Kolves et al 2014[32]	Europe	large	10–14	1990–2009	Suicide
Laido et al 2016[36]	Austria	~500 000	10–14	2001–2014	Suicide X60-X84
Lehti et al 2012[46]	Finland	~900 000	1–14, 1–4, 5–9, 10–14	2000–2009	Assault
Madge et al 1999[37]	Several countries	large	10–14	1990–1994	Suicide E950-959
Makhlouf et al 2014[44]	Garches (France)	~650 000	1–15	1991–2008	Assault
Malone et al 2009[51]	Ireland	~300 000	5–14	1993–2008	Suicide

Reference	Country, Region	Source population size	Age groups	Years studied	Outcomes 1)
Mattila et al 2005[48]	Finland	~300 000	10–14	1990–2002	All external
McClure et al 2000[28]	England & Wales	~3 500 000	10–14	1990–1998	Suicide, Undetermined
Meyer et al 2012[52]	Germany	~12 000 000	1–4, 5–9, 10–14	2000–2008	Suffocation/Strangulation W75-W80
Otterman et al 2019[19]	Sweden	~1 500 000	1–14	2000–2014	Transport-related V01-V99, Y85; Other external, non-intentional W00-X38, X40-X59, Y83.6-Y84.8 and Y86.0-Y86.9; Suicide X60-X84, Assault X85-Y09, Y36.9; Undetermined Y10-Y34
Pakkari et al 2013[13]	Finland	~900 000	1–4, 5–9, 10–14	1990–2010	All external
Pakkari et al 2016[14]	Finland	~300 000	10–14	1990–2013	All external
Pearson et al 2009[18]	Scotland	~900 000	1–4, 5–9, 10–14	1992–2006	All external V01-Y98
Pearson et al 2009[15]	Scotland	~800 000	1–4, 5–9, 10–14	2002–2006	Road traffc injuries* V01–29, V40–49, V70–79; Falls W00–19, Exposure to inanimate mechanical forces W20–49, Drowning W65-W74, Suffocation/Strangulation W75-W84, Fire X00-X09**, Poisoning X40-X49, Suicide X60–84, Y10–34; Assault X85-Y09, Y10-Y34***
Pritchard et al 2005[34]	Global	large	5–14	1997–1999	Suicide X60-X84, Undetermined Y01-Y34, Y87, Y89
Qirjako et al 2008[26]	Tirana (Albania)	~99 000	1–14, 1–4, 5–9, 10–14	2000–2005	Road accident*

Reference	Country, Region	Source population size	Age groups	Years studied	Outcomes 1)
Redmore et al 2016[38]	England & Wales	~3 500 000	10–14	2002–2011	Suicide X60–X84, Y10-Y34, Y87.0, Y87.2
Roh et al 2018[33]	Global	large	10–14	varies, 1995–2012	Suicide X60-X84
Sengoelge et al 2010[21]	Europe	large	1–4, 5–9, 10–14	2002–2004	Home accident X40-Y86****
Sidebotham et al 2011[45]	E & W	~11 000 000	1–14, 1–15	1990–2008	Assault X85–Y09, Undetermined Y10–Y34, U50.9
Steck et al 2018[39]	Switzerland	~2 400 000	10–14	1991–2013	Suicide X60-X84
Strukcinskiene et al 2011[23]	Lithuania	~500 000	1–4, 5–9, 10–14	1990–2008	Road traffc injuries*
Töro et al 2006[53]	Hungary	~1 200 000	5–9, 10–14	1990–2003	Accidental falls W11-W17, W19; Intentional falls X80, Intent undetermined Y30
Töero et al 2011[11]	Budapest (Hungary)	~100 000	10–14	1994–1998	Suicide
Viner et al 2011[49]	Global	large	1–9, 5–14	1990–2005	All external
Vougiouklakis et al 2009[12]	Epirus (Greece)	10 000–30 000	10–14	1998–2008	Suicide
Vähätalo et al 2014[54]	Uusimaa (Finland)	~250 000	1–4, 1–15, 5–12	1997–2007	Drowning
Väli et al 2007[16]	Estonia	~200 000	1–4, 5–9, 10–14	2001–2005	All external, Transport-related, Falls Hit by object (Inanimate mechanical force), Drowning, Suffocation/strangulation, Poisoning, Suicide, Assault, Undetermined
Windfuhr et al 2008[40]	UK	~3 000 000	10–14	1997–2003	Suicide X60-X84, X87.0, Y10-34, Y87.2
Windfuhr et al 2013[41]	E & W	~3 500 000	10–14	2001–2010	Suicide X60-X84, Y87.0; Undetermined Y10-Y34, Y87.2

Reference	Country, Region	Source population size	Age groups	Years studied	Outcomes 1)
Yu et al 2016[24]	Denmark, Sweden, Finland	~7 000 000	1–4, 5–9	1990–2010	Transport-related V01-V99

1)International Classification of diseases (ICD) codes if provided, latest revision
*Discussed with V01-V99, transport-related
**Discussed with W85-X19, burns
***Varies with age group
****Fourth digit 0, e.g. X40.0

3.3 Risk of bias

Results of the bias assessment according to the Joanna Briggs critical appraisal checklist are shown in *Supplementary Table 3* (10). Question 5 was not applicable for the present context, as there rarely is loss of participants in register-based studies assessing mortality. In general, the risk of bias was evaluated low. Crude numbers of deaths and sample sizes were consistently reported and sample sizes covered entire populations in most selected articles. In two articles it was unclear if the sample size was adequate considering the rare occurence of child suicide (11,12).

3.4 All non-natural deaths

Deaths due to external causes contributed 24%–40% to all recorded deaths (13–15). AMRs per 100 000 varied from 2·3 to 20·4 between different age groups and sexes (13,16). Several studies reported bimodal distribution with peak mortality rates in 1–4 and 10–14 age groups and the lowest rates for 5–9 year olds (13,17,18). Male predominance existed in most studies within nearly all age groups and cause-of-death subcategories, ranging from a ratio of 1:1 to 1:4 (13,14,17,18). In Nordic countries, a downward temporal trend in AMRs in non-intentional deaths (transport-related deaths and drownings) has been reported

both in Finland from 1990 to 2010 and Sweden from 2000 to 2014 (13,19). Similar trend was observed in Scotland from 1992–2006 with male mortality rates decreasing more steeply, reducing or closing the gap between sexes (18). Geographical gradients between Eastern and Western Europe were found in a study by Armour-Marshall (2012), with temporal trends of absolute difference in AMRs decreasing and relative difference increasing from 1993 to 2008 (20).

3.5 Transport-related deaths

In the early 2000s, transport-related injuries contributed to half of all non-natural deaths in age groups 5–9 and 10–14 in Europe (21), thus being the most common external cause of death in those age groups (15–17,21,22). Of all AMRs per 100 000 presented in this review, the lowest were observed in Sweden (0·87, children aged 1–14, from 2000 to 2014) (19) and the highest, 7·09, in Lithuania for 10–14 year old boys in 1990–2008 (23). Väli et al. reported high AMRs in Estonia (2001–2005) as well, 5·2–5·4 per 100 000 in all age groups (16), this being roughly 5-fold compared to neighbouring Nordic countries (24). Differences in AMRs between age groups in Estonia were minor (16). In Poland and Scotland, higher AMRs were discovered in older age groups (15,17). Also, the gap between sexes increased with age in Poland with male majority in older age groups (17). Bacopoulou et al. estimated male to female (M:F) ratio to be 2:1 for 10-14 year olds in Greece in the 2000s (22). Similarly in a study from France, M:F ratio was 1·9:1 for children under 10 years (25). In Tirana, Albania, this ratio was as high as 4:1 for 1- to 14-year-olds in the early 2000s (26).

Overall, temporal trends were found to be decreasing (17,19,23,24). In Lithuania, reduction in transport-related deaths was more prominent for girls aged 1–4 and boys aged 10–14 (23). Yu et al. studied Nordic countries, in which the AMRs for both sexes appeared to converge in the study period of 1990–2010, settling at approximately 1 per 100 000 in 2010 (24).

3.6 Other non-intentional accidental deaths

ICD-codes W01–X59 were included in this group, for which only one article reported an AMR of 1·02 per 100 000 considering all children aged 1 to 14 in Sweden (19). In this group, major subgroups the articles dealt with were drowning, poisoning, jumping/falling, and suffocation/strangulation deaths. Mortality data on specific causes of death was relatively sparse, as there were only few data points on a single group of causes. No article dealt with deaths due to natural disasters or contact with venomous plants or animals.

Grajda et al. found drowning to be the second most common external cause of death among children in Poland, surpassed by transport-related injuries (17). In Estonia similar numbers were observed in the early 2000s for the age group 5-9. Among 1–4 year olds, drowning is the leading external cause of death, followed by transport-related injuries. For the oldest age group 10–14, drowning was third most common as suicides became more prevalent (16). Strangulation and fire-related deaths were common in younger age groups in Scotland in the mid-2000s (15).

As absolute numbers for cause of death subgroups were low, temporal trends were frequently not reported. Kivistö et al. observed a slightly decreasing trend in the poisoning deaths in 5–15 year olds from the mid 1990s to early 2000s, taking into account both unintentional and intentional deaths (27).

3.7 Suicides

Suicides in children below the age of 10 were uncommon. No suicides in children under 10 years of age were observed in England & Wales from 1990 to 1998 or in Budapest, Hungary from 1994 to 1998 (11,28). Over a 5 year period in the Netherlands from 2013 to 2017, a total of 23 under-10 suicides were recorded

(29),meanwhile only one and two under-10 suicides were recorded in Austria (1990-2001) and Bosnia & Herzegovina (2002-2006), respectively (30,31).

Overall, AMRs per 100 000 due to self harm were, in the 10–14 age group, ranging from 0·1 in both Greece to 2·6 in Estonia (16,22). Child suicides were most prevalent in eastern Europe (32), while southern and southeastern European countries possessed the lowest AMRs for suicide (33). Pritchard et al. studied suicides in the age group 5–14 in Western countries with an excess of 16 million people in 1997–1999, discovering the highest AMRs due to self harm in the Netherlands and the lowest in England & Wales, Italy and Spain (34). Most common method seemed to be hanging (29,30,35–41). Second most common method varied significantly between countries and sexes, being either self-poisoning (30,37,40), using a firearm (30,35,37), or jumping from height, or in front of a moving object (29,36,39). M:F ratio of circa 2:1 was observed in several studies (22,29,30,36,37,39). Temporal trends were decreasing in Austria (2001–2014) and Poland (1999–2012) (17,36), while in Sweden (2000–2014) and Switzerland (1991–2013), AMRs were steady (19,39). Overall in Europe, suicide rates for boys decreased from 1990 to 2009, while no change in girl's suicide rates were observed (32).

3.8 Assaults

AMRs for assault ranged from 0·22 per 100 000 in Sweden to 0·8 per 100 000 in the city of Belgrade, Serbia (1991–2005) (19,42). Assaults were more common in younger age groups in Scotland and Belgrade (15,42). In Belgrade, while firearms were more prevalent in assaults towards older children, blunt injuries were most commonly found in younger children. Similar trends were observed in both the Institute of Forensic Medicine of Paris (1990–1993) and Raymond Poincaré Hospital, France (1991-2008) (43,44). Slightly higher proportion of male child victims was observed in France. In England & Wales, AMRs decreased from 1990 to 2008 (45), while in Belgrade a slight increase was recorded (42). In

Sweden (2000–2014) and Finland (2000–2009) the rates remained unchanged (19,46).

3.9 Undetermined deaths

AMRs of undetermined deaths were available in seven out of eight articles on the subject (16,17,19,28,34,40,41,45). Seven articles discussed undetermined deaths in conjunction with suicides or assaults. Out of these seven, five articles concerned undetermined deaths in England & Wales, as in these countries a high level of certainty is required to designate an unnatural death to be due to self harm (28,40,41,45). In England & Wales (1990–2008) in the age group of 1–14, AMRs per 100 000 were 0·3–0·5 with no clear temporal trends observed (45). This number was lower in Sweden (2000–2014), being 0·11 for the same age group (19). AMRs were highest for children aged 1–4 in Estonia (2001–2005), 1·6 (16). In addition, no undetermined deaths were recorded for 5–9 year olds in Estonia. In Poland (1999–2012), AMRs were more even between different age groups, ranging from 0·3–0·7 (17). Pritchard et al. studying several larger European countries (1997–1999) found AMRs for undetermined deaths to be highest in Germany, 1·3, while in the Netherlands no undetermined deaths were recorded during the same time period (34).

4 DISCUSSION

This systematic literature review provides a comprehensive summary of non-natural deaths among children in Europe aged 1–15. The main finding was that the trend in non-natural mortality among children is decreasing in Europe. While

transport related accidents remain to be the leading external cause of death for younger age groups and constitutes a significant portion of deaths among children aged 5 and above, epidemiology of suicides was the most studied topic in the class of non-natural deaths.

Systematic reviews addressing incidence data are of key importance to policy makers and social and health professionals when developing more effective preventive strategies, and in the case of the present review, reducing non-natural mortality among children in Europe. In addition, the rationale of the present review was to serve as a comprehensive basis for subsequent research studies addressing non-natural mortality.

4.1 Main findings and policy implications

Reductions were seen in both transport-related and other accidental deaths. Suicides seemed to decrease or stayed at the same level as before, and assaults were either steady or slightly increasing. Reductions in fatal self-harm were mostly due to a decrease in the number of male suicides. Still, a gap between sexes exists in all non-natural deaths with male predominance, although it is narrowing. Income inequality is another obstacle to be tackled.

In another study focusing on the World Health Organization (WHO) European region, nearly a 50% decline in non-natural deaths of children aged 0–14 from 2000 to 2015 was observed, mostly due to the decrease in intentional deaths (55%) compared to non-intentional (46%) (47). Income inequality was seen as a worsened ratio in accidental deaths (mainly transport-related deaths) between high- and low-to-middle-income countries. This might be due to lower priority of the prevention of road traffic accidents. On the contrary, the ratio of suicides and assaults actually improved.

Decline in non-intentional accidental deaths is probably ascribed to improvements in traffic planning, road safety measures, and trauma care

(13,14,19,22,38,48); water safety campaigns, swimming education, and surveillance (17,19). Suicide prevention is challenging due to the easy accessibility of most common methods, such as hanging oneself or jumping from height (12,38). Possible measures to prevent suicides committed by jumping from height are restricting access to the hot spots and railways and adding fences (29,36). Early intervention to self-harm in childhood is of great importance, but not an easy task by any means. School and primary health care personnel play a major role in detecting self-harm or suicidality and in mental health promotion (30,36,38).

4.2 Future prospects

In principle, most non-natural deaths are preventable. This was reflected in the results of this study as geographical variation in AMRs. As a way of estimating the rough number of preventable deaths, one could count the number of deaths, if the region matched the lowest AMRs in Europe, and then subtract the result from the actual number of deaths. From 1990 to 2008, approximately half of transport-related deaths and more than 90% of other non-intentional deaths could be averted in the age group 0–14 as the mortality rate differences were more than tenfold between different European countries (47). In addition, further reductions can be achieved. A promising sign is that in the studies included in the present review, decreasing AMRs were observed in the countries with already the least number of injury deaths.

In the present review a fourfold increase in the number of articles was observed from the 90s to the 2000s (Table 1). A lack of articles studying 2010s was evident, as the number of articles halved moving from the 2000s. This is a major finding, as the importance of prevention of non-natural deaths among children has not changed. In order to keep ourselves up-to-date, more epidemiological studies addressing this subject are needed.

Vital statistics are easily accessible as part of civil registries in Europe (13,14,16,19,30,48). Studying mortality characteristics is therefore manageable on a country level. Yet, there are challenges to overcome, such as underreporting and incorrect classification of certain cases of non-natural deaths, mostly in the event of fatal self-harm of a child (3,12,30,37). The reliability and accessibility of autopsy records is a problem on a global scale, the issue being prevalent in lower income countries of Asia and Africa in particular (49). For example, in some Sub-Saharan countries information on autopsy data might be only gained on a verbal basis (3). It might be due to these issues, least research is conducted on external cause mortality in the poorest countries, while on the contrary, they possess the highest mortality rates.

It is challenging to evaluate global trends in child external cause mortality due to the unavailability of appropriate data and a lack of studies in this age group (2). The leading non-natural causes of death vary globally (2,3), but are most commonly either transport-related deaths or drownings. Imamura et al. found drowning to be especially common in children aged 1–4 in several countries (3), while in Africa burns contribute to around one in four non-natural deaths of the same age group, and transport related deaths represent 22% of all external cause deaths (2). While transport-related accidents are common, other unintentional deaths combined form a major entity comparable to the amount of traffic deaths (3). Notable non-intentional causes-of-death globally in addition to drowning are falls, accidental poisoning, and strangulation (3,5).

4.3 Study limitations

Problems encountered during the data collection were related to non-uniform age groups and outcome definitions, considering that two different versions of ICD coding were used. Another challenge was that AMRs were not always reported, and in the case that a crude amount of deaths was reported, population size was not always mentioned. In the future, studying infants aged 0–1 and children over the age of 1 separately is recommended. The developmental stage, daily

activities, and interaction with the world differ greatly between these age groups. Considering infants, suffocation is a major non-natural cause-of-death (3). In addition, cause-of-death documentation/certification should follow the relevant ICD coding, and population sizes should be clearly stated in the methods. However, the risk of bias was evaluated to be low in the reviewed articles. This was anticipated, as reliable and comprehensive sources of mortality data such as national, local registries of authorities and autopsy data from forensic institutes were used in all articles.

It should be noted that morbidity due to external causes wasn't evaluated in the present review. These injuries contribute to millions of emergency room visits and hospitalizations in children under 20 years of age (5).

5 CONCLUSIONS

This systematic review summarized epidemiological papers on non-natural deaths of children aged 1–15 in the European region from 1990 to the present day. A decline in the absolute number of non-natural deaths was observed during the study period. Accidental deaths decreased more than intentional deaths. Drowning was the most common external cause-of-death in the youngest age group, while in the older age groups transport-related injuries contributed most to unnatural deaths. Similarities in the leading non-natural causes-of-death were found in Europe and globally, with the exception of burns being more prevalent in some African countries. A global comparison of AMRs and temporal trends is difficult due to the lack of studies on a global level on our age group of interest. More research is needed on non-natural deaths of children aged 1 and above on both national and continental (European) level. Accidental deaths other than

transport-related are the least studied non-natural causes-of-death, although they contribute a significant portion to child mortality.

6 REFERENCES

1 Peden M, Oyegbite K, Ozanne-Smith J, *et al.* World report on child injury prevention. *World Health Organization and United Nations Children's Fund*, Geneva 2008.

2 Adeloye D, Bowman K, Chan KY, Patel S, Campbell H, Rudan I. Global and regional child deaths due to injuries: An assessment of the evidence. *J Glob Health* 2018; **8**: 1–11.

3 Imamura JH, Troster EJ, de Oliveira CAC. What types of unintentional injuries kill our children? Do infants die of the same types of injuries? A systematic review. *Clinics* 2012; **67**: 1107–16.

4 Petridou E. Childhood injuries in the European Union: can epidemiology contribute to their control?. *Acta Paediatr* 2000; **89**: 1244–9.

5 Sethi D, Towner E, Vincenten JA, Segui-Gomex M, Racioppi F. European report on child injury prevention. *World Health Organization*, Geneva 2008.

6 World Health Organization. *International Classification of Diseases, ninth revision Volumes I and II.* Geneva 1977 and 1978.

7 World Health Organization. *International Statistical Classification of Diseases and Related Health Problems, tenth revision Volume I.* Geneva 1992.

8 ospguides.ovid.com/OSPguides/medline.htm. *MEDLINE® 2021 Database Guide.* Accessed 27 April 2021

9 populationpyramid.net. *Population Pyramids of the World from 1950 to 2100*. Accessed 27 April 2021.

10 Munn Z, Moola S, Lisy K, Riitano D, Tufanaru C. Methodological guidance for systematic reviews of observational epidemiological studies reporting prevalence and incidence data. *Int J Evid Based Healthc.* 2015; **13**: 147–153.

11 Toero K, Nagy A, Sawaguchi T, Sawaguchi A, Sotonyi P. Characteristics of suicide among children and adolescents in Budapest. *Pediatr Int* 2001; **43**: 368–71.

12 Vougiouklakis T, Tsiligianni C, Boumba VA. Children, adolescents and young adults suicide data from Epirus, northwestern Greece. *Forensic Sci Med Pathol* 2009; **5**: 269–73.

13 Parkkari J, Mattila V, Kivisto J, Niemi S, Palvanen M, Kannus P. Fatal childhood injuries in Finland, 1971-2010. *Inj Prev* 2013; **19**: 171–6.

14 Parkkari J, Sievanen H, Niemi S, Mattila VM, Kannus P. Injury deaths in the adolescent population of Finland: a 43-year secular trend analysis between 1971 and 2013. *Inj Prev* 2016; **22**: 239–46.

15 Pearson J, Stone DH. Pattern of injury mortality by age-group in children aged 0-14 years in Scotland, 2002-2006, and its implications for prevention. *BMC Pediatr* 2009; **9**: 26.

16 Vali M, Lang K, Soonets R, Talumae M, Grjibovski AM. Childhood deaths from external causes in Estonia, 2001-2005. *BMC Public Health* 2007; **7**: 158.

17 Grajda A, Kulaga Z, Gurzkowska B, Gozdz M, Wojtylo M, Litwin M. Trends in external causes of child and adolescent mortality in Poland, 1999-2012. *Int J Public Health* 2017; **62**: 117–26.

18 Pearson J, Jeffrey S, Stone DH. Varying gender pattern of childhood injury mortality over time in Scotland. *Arch Dis Child* 2009; **94**: 524–30.

19 Otterman G, Lahne K, Arkema E V, Lucas S, Janson S, Hellstrom-Westas L. Childhood death rates declined in Sweden from 2000 to 2014 but deaths from external causes were not always investigated. *Acta Paediatr* 2019; **108**: 160–8.

20 Armour-Marshall J, Wolfe I, Richardson E, Karanikolos M, McKee M. Childhood deaths from injuries: trends and inequalities in Europe. *Eur J Public Health* 2012; **22**: 61–5.

21 Sengoelge M, Hasselberg M, Laflamme L. Child home injury mortality in Europe: a 16-country analysis. *Eur J Public Health* 2011; **21**: 166–70.

22 Bacopoulou F, Petridou E, Korpa TN, Deligeoroglou E, Chrousos GP. External-cause mortality among adolescents and young adults in Greece over the millennium's first decade 2000-09. *J Public Health (Oxf)* 2015; **37**: 70–7.

23 Strukcinskiene B. Traffic death trends in children aged 0-14 years in Lithuania: patterns by age group. *Int J Inj Contr Saf Promot* 2011; **18**: 299–304.

24 Yu Y, Qin G, Cnattingius S, *et al.* Mortality in Children Aged 0-9 Years: A Nationwide Cohort Study from Three Nordic Countries. *PLoS One* 2016; **11**: e0146669.

25 Javouhey E, Guerin A-C, Amoros E, *et al.* Severe outcome of children following trauma resulting from road accidents. *Eur J Pediatr* 2006; **165**: 519–25.

26 Qirjako G, Burazeri G, Hysa B, Roshi E. Magnitude and fatality from road accidents among children in Tirana, Albania. *Med Arh* 2008; **62**: 100–1.

27 Kivisto JE, Parkkari J, Mattila VM, Hoppu K. Poisoning deaths among Finnish children from 1969 to 2003. *Acta Paediatr* 2009; **98**: 1661–6.

28 McClure GM. Suicide in children and adolescents in England and Wales 1970-1998. *Br J Psychiatry* 2001; **178**: 469–74.

29 Berkelmans G, van der Mei R, Bhulai S, Merelle S, Gilissen R. Demographic Risk Factors for Suicide among Youths in The Netherlands. *Int J Environ Res Public Health* 2020; **17**.

30 Dervic K, Friedrich E, Oquendo MA, Voracek M, Friedrich MH, Sonneck G. Suicide in Austrian children and young adolescents aged 14 and younger. *Eur Child Adolesc Psychiatry* 2006; **15**: 427–34.

31 Fajkic A, Lepara O, Voracek M, *et al.* Child and adolescent suicides in Bosnia and Herzegovina before and after the war (1992-1995). *Crisis* 2010; **31**: 160–4.

32 Kolves K, De Leo D. Suicide rates in children aged 10-14 years worldwide: changes in the past two decades. *Br J Psychiatry* 2014; **205**: 283–5.

33 Roh B-R, Jung EH, Hong HJ. A Comparative Study of Suicide Rates among 10-19-Year-Olds in 29 OECD Countries. *Psychiatry Investig* 2018; **15**: 376–83.

34 Pritchard C, Hansen L. Child, adolescent and youth suicide and undetermined deaths in England and Wales compared with Australia, Canada, France, Germany, Italy, Japan and the USA for the 1974-1999 period. *Int J Adolesc Med Health* 2005; **17**: 239–53.

35 Groholt B, Ekeberg O, Wichstrom L, Haldorsen T. Suicide among children and younger and older adolescents in Norway: a comparative study. *J Am Acad Child Adolesc Psychiatry* 1998; **37**: 473–81.

36 Laido Z, Voracek M, Till B, *et al.* Epidemiology of suicide among children and adolescents in Austria, 2001-2014. *Wien Klin Wochenschr* 2017; **129**: 121–8.

37 Madge N. Youth suicide in an international context. *Eur Child Adolesc Psychiatry* 1999; **8**: 283–91.

38 Redmore J, Kipping R, Trickey A, May MT, Gunnell D. Analysis of trends in adolescent suicides and accidental deaths in England and Wales, 1972-2011. *Br J Psychiatry* 2016; **209**: 327–33.

39 Steck N, Egger M, Schimmelmann BG, Kupferschmid S, Cohort SN. Suicide in adolescents: findings from the Swiss National cohort. *Eur Child Adolesc Psychiatry* 2018; **27**: 47–56.

40 Windfuhr K, While D, Hunt I, *et al.* Suicide in juveniles and adolescents in the United Kingdom. *J Child Psychol Psychiatry* 2008; **49**: 1155–65.

41 Windfuhr K, While D, Hunt IM, Shaw J, Appleby L, Kapur N. Suicide and accidental deaths in children and adolescents in England and Wales, 2001-2010. *Arch Dis Child* 2013; **98**: 945–50.

42 Baralic I, Savic S, Alempijevic DM, Jecmenica DS, Sbutega-Milosevic G, Obradovic M. Child homicide on the territory of Belgrade. *Child Abuse Negl* 2010; **34**: 935–42.

43 Fornes P, Druilhe L, Lecomte D. Childhood homicide in Paris, 1990-1993: a report of 81 cases. *J Forensic Sci* 1995; **40**: 201–4.

44 Makhlouf F, Rambaud C. Child homicide and neglect in France: 1991-2008. *Child Abuse Negl* 2014; **38**: 37–41.

45 Sidebotham P, Atkins B, Hutton JL. Changes in rates of violent child deaths in England and Wales between 1974 and 2008: an analysis of national mortality data. *Arch Dis Child* 2012; **97**: 193–9.

46 Lehti M, Kääriäinen J, Kivivuori J. The declining number of child homicides in Finland, 1960-2009. *Homicide Stud* 2012; **16**: 3–22.

47 Sethi D, Aldridge E, Rakovac I, Makhija A. Worsening Inequalities in Child Injury Deaths in the WHO European Region. *Int J Environ Res Public Health* 2017; **14**.

48 Mattila VM, Parkkari J, Niemi S, Kannus P. Injury-related deaths among Finnish adolescents in 1971-2002. *Injury* 2005; **36**: 1016–21.

49 Viner RM, Coffey C, Mathers C, *et al.* 50-year mortality trends in children and young people: a study of 50 low-income, middle-income, and high-income countries. *Lancet (London, England)* 2011; **377**: 1162–74.

50 Davies K, Johnson EL, Hollen L, *et al.* Incidence of medically attended paediatric burns across the UK. *Inj Prev* 2020; **26**: 24–30.

51 Malone KM, Quinlivani L, McGuinness S, McNicholas F, Kelleher C. Suicide in children over two decades: 1993-2008. *Ir Med J* 2012; **105**: 231–3.

52 Meyer FS, Trubner K, Schopfer J, *et al.* Accidental mechanical asphyxia of children in Germany between 2000 and 2008. *Int J Legal Med* 2012; **126**: 765–71.

53 Toro K, Szlavik N, Meszaros A, Dunay G, Soos M, Keller E. Jumping and falling death in children, adolescents, and young adults. *J Clin Forensic Med* 2006; **13**: 129–34.

54 Vahatalo R, Lunetta P, Olkkola KT, Suominen PK. Drowning in children: Utstein style reporting and outcome. *Acta Anaesthesiol Scand* 2014; **58**: 604–10.

7 ATTACHMENTS

Supplementary Table 1. Non-natural causes of death and corresponding International Classification of Diseases (ICD) codes.

Cause of death	ICD-9	ICD-10
All external causes	E800–E999	V00–Y98
Accidents	E800–E848, E850–E869, E880–E949	V00–X59
Transportation accidents	E800–E848	V00–V99
Other accidents	E850–E869, E880–E949	W00–X59
Falls	E880–E888	W00–W19
Mechanical forces	E906, E916–923	W20–W64
Drowning	E910	W65–W74
Suffocation	E911–E913	W75–W84
Burns	E890–E899, E902, E907, E924–E926	W85–X19
Venomous plants and animals	E905	X20–X29
Forces of the nature	E900–E901, E908–E909	X30–X39
Poisoning	E850–E869	X40–X49
Overexertion	E927	X50
Other specified factors	E928	X57–X59
Suicide	E950–E959	X60–X84
Assault/homicide	E960–E969	X85–Y09
Undetermined	E980–E989	Y10–Y34
Legal intervention, operations of war, military operations, and terrorism	E970–E979, E990–E999	Y35–Y36
Medical errors	E870–E879	Y40–Y84

Supplementary Table 2. The search syntax used in the OvidMEDLINE database.

1. exp Homicide/
2. Suicide/
3. exp Accidents/mo [Mortality]
4. exp Armed Conflicts/
5. undetermined manner of death.mp.
6. undetermined cause of death.mp.
7. unnatural death.mp.
8. non-natural death.mp.
9. fatal injury.mp.
10. external cause.mp.
11. exp Drowning/
12. exp Asphyxia/mo [Mortality]
13. exp Poisoning/mo [Mortality]
14. exp "Wounds and Injuries"/mo [Mortality]
15. exp Child Abuse/mo [Mortality]
16. exp Medical Errors/mo [Mortality]
17. 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16
18. exp *adolescent/ or exp *child/ or exp child mortality/ (adolescen* or boy? or boyfriend or boyhood or child* or girl? or juvenil* or kid? or minors or minors* or preschool* or puber* or pubescen* or school* or teen* or underage? or under-age? or youth*).ti,kf.
19. 17 and 18
20. limit 19 to (abstracts and english language and humans and yr="1990 -Current")
21. exp Europe/
22. 20 and 21

3 March 2021: 744 results

Supplementary Table 3. Risk of bias evaluated using the critical appraisal checklist developed in Joanna Briggs Institute (10).

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9		
Armour-Marshall et al	Y	Y	Y	Y	-	Y	Y	Y	Y		Y = Yes
Bacopoulou et al	Y	Y	Y	Y	-	Y	Y	Y	Y		N = No
Baralic et al	Y	Y	Y	Y	-	Y	Y	Y	Y		? = Unclear
Berkelmans et al	Y	Y	Y	Y	-	Y	Y	Y	Y		- = Not applicable
Davies et al	Y	Y	Y	Y	-	Y	Y	Y	Y		
Dervic et al	Y	Y	Y	Y	-	Y	Y	Y	Y		
Fajkic et al	Y	Y	Y	Y	-	Y	Y	Y	Y		
Fornes et al	Y	Y	Y	Y	-	Y	Y	Y	Y		
Grajda et al	Y	Y	Y	Y	-	Y	Y	Y	Y		
Groholt et al	Y	Y	Y	Y	-	Y	Y	Y	Y		
Javouhey et al	Y	Y	Y	Y	-	Y	Y	Y	Y		
Kivistö et al	Y	Y	Y	Y	-	Y	Y	Y	Y		
Kolves et al	Y	Y	Y	Y	-	Y	Y	Y	Y		
Laido et al	Y	Y	Y	Y	-	Y	Y	Y	Y		
Lehti et al	Y	Y	Y	Y	-	Y	Y	Y	Y		
Madge	Y	Y	Y	Y	-	Y	Y	Y	Y		
Makhlouf et al	Y	Y	Y	Y	-	Y	Y	Y	Y		
*Malone et al**	Y	Y	Y	Y	-	Y	Y	Y	Y		
Mattila et al	Y	Y	Y	Y	-	Y	Y	Y	Y		
McClure	Y	Y	Y	Y	-	Y	Y	Y	Y		
Meyer et al	Y	Y	Y	Y	-	Y	Y	Y	Y		
Otterman et al	Y	Y	Y	Y	-	Y	Y	Y	Y		
Parkkari et al	Y	Y	Y	Y	-	Y	Y	Y	Y		
Parkkari et al	Y	Y	Y	Y	-	Y	Y	Y	Y		
Pearson et al	Y	Y	Y	Y	-	Y	Y	Y	Y		
Pearson et al	Y	Y	Y	Y	-	Y	Y	Y	Y		
Pritchard et al	Y	Y	Y	Y	-	Y	Y	Y	Y		
Qirjako et al	Y	Y	Y	Y	-	Y	Y	Y	Y		

Redmore et al	Y	Y	Y	Y	-	Y	Y	Y	Y		
Roh et al	Y	Y	Y	Y	-	Y	Y	Y	Y		
	Q1	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Q7**	**Q8**	**Q9**		
Sengoelge et al	Y	Y	Y	Y	-	Y	Y	Y	Y		Y = Yes
Sidebotham et al	Y	Y	Y	Y	-	Y	Y	Y	Y		N = No
Steck et al	Y	Y	Y	Y	-	Y	Y	Y	Y		? = Unclear
Strukcinskiene	Y	Y	Y	Y	-	Y	Y	Y	Y		- = Not applicable
Töro et al	Y	Y	Y	Y	-	Y	Y	Y	Y		
Töero et al	Y	Y	?	Y	-	Y	Y	Y	Y		
Viner et al	Y	Y	Y	Y	-	Y	Y	Y	Y		
*Vougiouklakis et al***	Y	Y	?	Y	-	Y	Y	?	Y		
Vähätalo et al	Y	Y	Y	Y	-	Y	Y	Y	Y		
Väli et al	Y	Y	Y	Y	-	Y	Y	Y	Y		
Windfuhr et al	Y	Y	Y	Y	-	Y	Y	Y	Y		
Windfuhr et al	Y	Y	Y	Y	-	Y	Y	Y	Y		
Yu et al	Y	Y	Y	Y	-	Y	Y	Y	Y		

*Apparently suicide rates were calculated for the age group of 10–14 instead of 5–14
**The denominator for calculating annual mortality rates seemed to be incorrect